COSEE: Origins, Evolution, and Future

Developments in Educational Reform That Initiated COSEE

The ocean sciences community was faced with big challenges 10 years ago

In the mid-1990s, a series of seminal national reports[1-3] ushered in a period of major reforms in science education. These reforms, now familiar to educators at all levels, emphasized inquiry-based learning over passive learning, integration of research and education, interconnecting themes over isolated content, technology-assisted learning, and standards-based curricula.

As the reform movement gained traction, the ocean sciences community saw the multidisciplinary value of its subject area as an opportunity to support science education reform.[4, 5] The intrinsic human interest in the world's ocean that is expressed in a multitude of creative human activities, from art to literature to navigation to science, should readily empower educators to use ocean sciences in implementing the national directive that "science should be integrated with other areas of the curriculum."[6] The science of the world's ocean is very broad, encompassing all of the STEM disciplines; ocean science is a venue to overcome a disadvantage of disciplinary sciences that "…their divisions do not necessarily match the way the world works, and they can make communication difficult."[5]

In spite of the potential for leadership in science education reform, ocean scientists and educators found that joining the reform movement presented some formidable challenges. There was no common ocean education focus for scientists and educators. Aquariums, museums, science centers, and marine laboratories were then, as now, valued vehicles for public education, but the research community lacked mechanisms for effectively engaging such institutions. The research community had no place to go for guidance in the unfamiliar task of sharing the fruits of ocean sciences research with a broader audience.

Well-planned programs of the National Oceanic and Atmospheric Administration (NOAA) in the 1980s and 1990s to coordinate educational programs on ocean and aquatic sciences brought change within NOAA's learning environments, but did not have a wide impact outside the agency. The critical mass necessary to propel ocean education into the consciousness of ocean scientists—and beyond to the mainstream education community—had not yet been achieved. To paraphrase a report[7] from the National Research Council, "education reform will not advance in a permanent way through the efforts of 'Lone Rangers'."

It had become clear that a new structure, national in scope and capable of integrating the efforts of multiple agencies and academic institutions with an ocean sciences mission, was going to be required in order to propel ocean sciences education into the forefront of the education reform movement and allow it to achieve its full potential.

Developments in geoscience education laid the groundwork for COSEE

Then a series of developments in the mid- to late-1990s built a momentum within geoscience education that created the opportunity for a wholly new approach to ocean sciences education.

– The introduction of the concept of Earth System Science (ESS) represented a paradigm shift in the study of the natural science and human dimensions of the Earth as an integrated system; the ocean was to be studied and understood in terms of its linkages to other system components.

– At the urging of its advisory committee, NSF's Directorate for Geosciences (GEO) established a Geoscience Education program[8], with an annual competition for "catalytic" small grants to start geoscience education projects in all education sectors and all geoscience disciplines.

– The National Science Board recommended[9] that NSF replace the four existing review criteria with two, one emphasizing intellectual merit, the other focusing on "broader impacts," which included bringing the fruits of scientific research to formal and informal education. In this context, NSF began to emphasize the imperative of the "integration of research and education."

– The Consortium for Oceanographic Research and Education (CORE) brought together ocean scientists and science educators in an NSF-sponsored workshop to develop formal partnerships between the ocean research and science education communities. The resulting partnership among COSEE, the National Geographic Society, the National Marine Educators Association, and NOAA led to the crafting of *Ocean Literacy: Essential Principles and Fundamental Concepts,* more involvement by scientists in K-12 formal and informal education and outreach, and an inventory of K-12 programs and curricula.

– The CORE workshop was the impetus for the National Oceanographic Partnership Program (NOPP) to fund three ambitious ocean educational projects: Consortium of Oceanographic Activities for Students and Teachers (COAST), Project Oceanography, and The Bridge: Ocean Sciences Education Teacher Resource Center. The success of these projects re-enforced the impression within the NSF that ocean sciences education was at a "crossroad of opportunity."

The CORE workshop findings foreshadowed the case that would be made for COSEE some years later:

– The ocean sciences are integral to a sound science education for young people and for a scientifically literate adult population.

– A number of partnerships already exist between ocean science researchers and K-12 educators, but they are isolated from each other and occur randomly.

– There are many examples of ocean sciences-related K-12 curriculum materials and programs, but they are not widely known or used by K-12 teachers.

– K-12 teachers are central to any discussion of, or approaches to, reforming and enhancing science education in our nation's schools.

– Research in the ocean sciences is significantly dependent on state-of-the-art technology and heavily reliant on remote and real-time access to data and resources; these features offer tremendous, untapped potential for K-12 education.

A key workshop recommended that NSF establish a program of support for COSEE

As a result of the momentum created by these developments, the question was asked within NSF: Has the time come to catalyze a paradigm shift in the relationship between the ocean sciences research community and educators, students, and the general public? In late 1999, the GEO and Education and Human Resources (EHR) Directorates and the Division of Ocean Sciences sponsored a preliminary meeting to begin to answer this question. In May 2000, a high-profile three-day workshop sponsored by NSF brought together 73 participants in Long Beach, Mississippi. The workshop participants were charged with recommending strategies by which NSF and other federal agencies could develop a nationally coordinated effort to improve and promote ocean sciences education for the benefit of society.

From the intense deliberations of the workshop emerged a principal recommendation: NSF should establish a new mechanism of support for a Centers for an Ocean Sciences Education Excellence program—consisting of *regional centers*—as a nationally coordinated program for formal and informal ocean education[10]. Its mission would be ambitious; COSEE would:

– facilitate the integration of research into high-quality educational materials to engage students in the excitement of discovery and understanding of the relevance of the ocean to their lives;
– educate the public about the influence of the ocean on the quality of their lives and the prosperity of the nation;
– assist in developing curricula with core competencies for more effective education;
– encourage the investigation of teaching and learning in integrated sciences;
– foster the inclusion of groups traditionally underrepresented and underserved in science;
– encourage the sound preparation of teachers;
– provide for professional development of teachers, undergraduate faculty, and administrators;
– assist in improving the reward structure for faculty and graduate student teaching;
– encourage the effective use of information technology;
– establish internships;
– provide career information across the spectrum of the ocean sciences;
– foster collaborations and partnerships both among people and organizations;
– formulate strategies to evaluate these initiatives.

NSF responded by convening a working group to make recommendations for a focused implementation of the program. This group met in early 2001, and the first COSEE program announcement was issued in the fall of 2001. A total of seven initial COSEE awards were made in the fall of 2002.

References

1. American Association for the Advancement of Science, 1993. *Benchmarks for Science Literacy*. Oxford University Press, New York.

2. National Research Council, 1996a. *National Science Education Standards*. National Academy Press, Washington, D.C.

3. National Science Foundation, 1996. Shaping The Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology, NSF 96-139, http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf96139

4. National Research Council, 1997. *Science Teaching Reconsidered: A Handbook*. National Academy Press, Washington, D.C.

5. American Association for the Advancement of Science, 1990b. *The Liberal Art of Science: Agenda for Action*. American Association for the Advancement of Science, Washington, D.C.

6. National Science Resource Center, 1997. *Science for All Children: A Guide to Improving Elementary Science Education in Your School District*. National Academy Press, Washington, D.C.

7. National Research Council, 1996b. *From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology*. National Academy Press, Washington, D.C.

8. National Science Foundation, 1997. Geoscience Education: A Recommended Strategy, A Report Based on an August 29-30, 1996, Workshop from the Geoscience Education Working Group to the Advisory Committee for Geosciences and the Directorate for Geosciences of the National Science Foundation (NSF 97-171), http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf97171.

9. National Science Board Resolution, 1997. Resolution approved by the National Science Board at its 342nd meeting, March 27-28, 1997, concerning new general criteria for merit review of proposals. NSB 97-72, March 1997.

10. McMannus, Dean A., Sharon H. Walker, Benjamin Cuker, Patricia Goodnight, Susan Humphris, Paula Keener-Chavis, Donald Reed, Veronique Robigou, Jerry Schubel. 2000. *Center for Ocean Science Education Excellence—The Report of a Workshop Sponsored by the National Science Foundation*, pp. 1-69.

Evolution of the National COSEE Network Over Its First Decade

Over the course of its first decade, COSEE has become a national force in helping to realize the broader impacts of ocean science research in advancing ocean literacy and developing a diverse workforce. It has developed into a robust and effective collaborative network of Centers, with an ability to project its mission broadly, while advancing the state of the art of ocean sciences education.

Developing a Collaborative National Network

The initial meeting of the Centers in 2002 turned out to be a pivotal moment for COSEE, as it was the first time that most of the PIs and evaluators thought in depth about the fact that the Centers needed to function as a cohesive network; the group began to consider how that might happen. It became clear that these diverse, individually funded Centers would need to find ways to work closely together in order to achieve the level of synergy and impact articulated in the COSEE vision. Given the diverse goals and work plans for each of the Centers, the PIs recognized that they needed to form a collaborative governance structure (the COSEE Council, formed in late 2003) that would be coordinated and supported by the Central Coordinating Office, but led by one of their peers (an elected Council Chair).

Given the range of goals and evaluation strategies developed by each Center, the evaluators for each Center recognized that they would need to find ways to identify common ground, avoid duplication of effort, and build a case for COSEE's collective impact. Although a national evaluator hired by the CCO has helped to coordinate these efforts, a formidable collaboration among the Center evaluators has become a key strength of the Network over time. The current Evaluation Working Group has taken the lead on compiling COSEE-wide data on key indicators such as scientist engagement.

Another key moment was the initial meeting of the National Advisory Board, at which COSEE received specific advice on how to function as a network. The NAB insisted that COSEE needed one logo and that the various naming conventions be dropped in favor of names that started with "COSEE". The PI's took this advice, adopted the COSEE logo, changed their names to fit the new model, and began to think as a network. This was followed by agreement on common website guidelines, which resulted in the creation of a robust national website supported by common content management and tools built into the individual Center sites.

Making the disparate Centers function as a network has required constant work – including careful development of a governance structure, cultivation of network leadership (including a rotating chair-elect/chair/past-chair structure), formation of permanent and ad hoc working groups, strategic planning, and active staff support and coordination from the CCO.

As the COSEE Network has grown in size and complexity, COSEE's network infrastructure has expanded in its capacity to provide for effective communication, collaboration, and decision-making. Governance procedures have been clarified and formalized. Permanent and ad hoc working groups have been established to manage key areas of work. Progress in implementing

the strategic plan is now monitored regularly, with the development of an annual operating plan each fall providing an opportunity to reflect on the past year's work, review changes in COSEE's internal and external working environment, and look ahead to the next year.

Projecting the COSEE Mission Broadly

COSEE's core mission is to fully engage scientists and educators in transforming ocean sciences education, thereby enabling the public to understand and fully appreciate the importance of the ocean to life on Earth in general and to the each human individual's life in particular.

COSEE has played an active role in elevating the profile of ocean sciences in the education community. At the initial strategic planning workshop for the National COSEE Network in 2004, participants recognized the power of the COSEE community to "speak with one voice" about ocean sciences literacy. COSEE, along with NMEA, National Geographic Society, and many others helped to formulate the Ocean Literacy Essential Principles and Fundamental Concepts. This roadmap to ocean literacy became a model for other disciplines, leading to similar documents on Climate Literacy, Energy Literacy, etc.

The US Ocean Commission also recognized COSEE's leadership role in communicating to the public the importance of the ocean and its relevance to their lives, and advocated for expanding COSEE as a key strategy in realizing its recommendations.

COSEE has developed a wide variety of innovative ways to broaden participation in ocean sciences research and education through targeted partnerships, recruitment strategies, customized programs, and pedagogical strategies. These are reflected in the work of nearly all the Centers, and are documented across the Network through common metrics that capture the ethnic/racial diversity of participants and, if educators are involved, the ethnic/racial audiences they serve.

COSEE has leveraged partnerships locally, regionally, and nationally in order to build its capacity for outreach. Regionally-focused Centers have built outreach networks involving multiple constituencies, such as a network of informal science education institutions in the Southeast, partnerships with the LA Unified School District in California, and formation of the New England Ocean Science Education Collaborative involving 40+ diverse institutions committed to ocean literacy.

Thematic Centers develop programs and resources that are then propagated throughout the network, focusing on key themes such as educational applications of data from ocean observing systems, use of concept mapping to build common ground between scientists and educators, and the impacts of rapid environmental changes on coastal areas.

COSEE has begun to spread its influence internationally with the formation of COSEE China; planning of collaborative arrangements with counterparts in several other countries has begun.

By partnering with professional associations such as AGU, NSTA, MTS, and others, COSEE has been able to create a national presence and visibility for its work among both science and education professionals.

Advancing the State of the Art of Ocean Sciences Education

COSEE has focused not only on expanding ocean literacy, but on advancing the state of the art of ocean science education as well. It has focused on innovation, creative use of technology, and promoting excellence through research, development, and reflection.

COSEE's National Advisory Committee (formerly National Advisory Board) keeps COSEE informed about key developments in research, technology, and education. Combined with annual strategic planning, this helps to keep COSEE looking forward and outward.

COSEE Working Groups, such as the Excellence in Networking Technology group, gather data on best practices from throughout the network and disseminate it to all via a web-based toolkit, case studies, and interactive webinars.

Once programs have been developed, tested, and found to be successful, they are then disseminated throughout the Network. For example, the Communicating Ocean Sciences course was originally developed by one Center, and then it was adapted by multiple Centers and disseminated to over 25 institutions across the country.

Each year, the network chooses a theme—such as teacher professional development, engaging scientists, broadening participation—to focus on best practices, producing a literature review, white paper on effective practices, and workshops for practitioners and evaluators. For example, COSEE's extensive work in teacher professional development has resulted in numerous best practices. A COSEE evaluation study demonstrated the beneficial impact (for both scientists and teachers) in having scientists deeply engaged in teacher professional development programs, as opposed to "one shot" involvement. This study has resulted in several Centers changing their practices to incorporate more meaningful scientist engagement with teachers.

COSEE's successful efforts in engaging scientists in education have resulted in an Education and Public Outreach Guide for Scientists (developed jointly by several Centers), as well as a set of case studies on the diverse ways in which scientists achieve broader impacts (13 case studies to be completed by December 2011).

COSEE's evolution over its first decade has followed a path of increasing Network integration, sophistication in outreach, and expansive outlook. It is poised to continue this evolution in the coming decade as it engages with ocean scientists to seize the many emerging opportunities in ocean technology, cyberinfrastructure, learning and communication science, and social networking.

A Vision of COSEE's Future[1]

The National Context

Culminating with the codification of the National Ocean Policy (NOP), the U.S. has completed a decade of high-level activities that underscore the importance of the ocean and ocean sciences to the Nation's economy and wellbeing. During this time, rapid advances in technology and access to information have initiated profound paradigm shifts in the ocean sciences research and science education enterprises. Fascinating new data and images from ocean observatories and research expeditions are providing scientists and the public with an unprecedented "window" into the ocean. Sophisticated models and visualizations are helping specialists and non-specialists alike to comprehend the complexity, dynamics, and significance of the ocean system. This decade of advances and the evolution of the NOP vision have laid the foundation for elevating the prominence of ocean sciences research and education to benefit the Nation.

The COSEE Context

The last decade has seen tremendous progress in the integration of ocean sciences research and education, driven in large part by the catalytic programs and activities of the National COSEE Network. COSEE has promoted ocean literacy, engaged scientists in broadening the impact of their research, and worked to increase the diversity of the ocean science workforce. Leveraging the interdisciplinary teams built within the Network, COSEE has impacted local, regional, and national ocean sciences education efforts through strategic planning, research and development, evaluation, and key partnerships.

Looking to the future, the Network has the opportunity and responsibility to leverage its capacity and connectivity to greatly increase its reach, as well as its impacts on ocean scientists, educators, and learners of all ages. COSEE is poised to address the priorities of the NOP within the context of new ocean sciences research initiatives, advances in technology, learning sciences research, and emerging expertise in effective network practices, Presently at a "tipping point," the Network has the potential to rapidly expand national and international awareness of the critical role that the ocean sciences play in the Nation' s economy, STEM education, and understanding global change.

Four priorities essential for a future National COSEE Network are described below. Each priority capitalizes on promising new and/or emerging opportunities, is grounded in COSEE accomplishments, and is supported by a vision for the future National COSEE Network.

Priority 1: A more cohesive and broader integration of ocean sciences research and education

Emerging programs within NSF such as the Ocean Observatories Initiative (OOI), Science Engineering and Education for Sustainability, and Science of Learning Centers offer a robust

[1] The COSEE community vision of the future is informed in part by the *Community Meeting on a Future Vision for COSEE and NSF Ocean Sciences Education* workshop report.

framework for advancing both interdisciplinary ocean sciences research and public appreciation and understanding of the ocean. The ocean sciences enterprise is rapidly developing new capabilities to observe, model, and predict the complex dynamics of the ocean. In a parallel trend, learning sciences research is providing insight into effective practices for incorporating authentic ocean sciences data and visualizations into a wide variety of learning environments.

The National COSEE Network has a proven track record in the development of education programs associated with NSF initiatives and is actively addressing the opportunities and challenges presented by the evolving technology for research and education. The necessary foundation now exists to systematically integrate NSF ocean sciences initiatives into educational products that use new ocean sciences data, tools, and other resources for teaching, learning, and discovery. Further capacity building within the Network will ensure the integration of ocean sciences research and education into the future.

Vision:
Ocean cyberlearning centers engage learners directly in ocean sciences research.

Virtual collaborative environments link researchers, educators, and learners for real-time ocean science learning and discovery.

Partnerships with organizations that create multimedia 3D visualization platforms (e.g. Google) facilitate ocean-related place-based learning opportunities.

An interdisciplinary career path integrates ocean sciences research and education.

Priority 2: A richer diversity of talent and perspectives advancing ocean sciences research and education

In a world where scientific and technical competitiveness and economic leadership are a function of the quality and diversity of human capital, the ocean sciences have failed to attract the kaleidoscope of diverse talent and perspectives that will be needed in the future workforce. Only 2% of ocean science professionals currently come from the non-white, non-Asian segments that make up 25-30% of our nation's population. By 2040, these demographic groups are expected to represent more than 40% of the U.S. citizenry. If the ocean sciences are to maintain their ability to contribute effectively to advancing STEM knowledge, the ocean sciences community must diversify its workforce.

In its first decade, COSEE has built a solid foundation for the difficult work that is needed to engage a wider spectrum of human capital and talent. COSEE's Diversity Working Group has created a knowledge base for promoting diversity in the ocean and Earth sciences. Network researchers are studying effective methods to engage and support a diversity of learners. COSEE has gained experience with recruitment and engagement programs at a variety of scales and in different geographic regions. Collaborations with key organizations such as the Institute for Broadening Participation and the Society for Advancing Chicanos and Native Americans in Science (SACNAS) have been forged. In bringing its knowledge, connections, and commitment to bear, COSEE will play a key role in future efforts to ensure a richer diversity of talent and perspectives within the ocean sciences community.

Vision:
COSEE leads communities of individuals and institutions with the range of requisite expertise to expand opportunities for all.

Collaborations with science communities that have demonstrated success at increasing diversity, e.g., engineering, inform COSEE programs and practices.

Strategies and tactics to increase the diversity of talent and perspectives in ocean sciences, including articulation of explicit metrics of success, are implemented throughout the Network.

A professional development continuum for students and younger ocean scientists ensures systemic change related to broadening participation in the ocean sciences.

Priority 3: A profound increase in the scope and stature of the ocean sciences education enterprise

The ocean remains the last frontier on Earth. Despite the lure of untold discoveries, charismatic creatures, and its vast expanse, widespread use of the ocean to engage students in science has not yet been realized. Technological advances in ocean sciences, a well-integrated research and education community, and the action of a unified and coordinated Network provide new avenues for COSEE to impact STEM education. Lifelong learning is increasingly taking place outside classrooms, presenting many exciting opportunities for COSEE to connect learners to the ocean in settings not traditionally considered.

In its first decade, COSEE played a pivotal role in elevating concepts central to an understanding of the ocean to a place of prominence in a wide arena within the formal-informal continuum of education. The Network contributed to the development, adoption, and dissemination of the unifying and transformative Ocean *Literacy: The Essential Principles of Ocean Sciences*. COSEE has promoted the inclusion of these principles in national and state science education standards, curriculum, and learning resources, and has provided input on the framework for the new National Science Education Standards, ensuring that ocean science will now be incorporated.

COSEE has experimented with multiple pathways to provide a breadth of opportunities to learn about the ocean. This has resulted in the production, implementation, and evaluation of a diversity of programs, materials, and strategies aimed at increasing an understanding of ocean science by a broad audience. An emerging thread in the Network is the inclusion of research on how people learn and the adoption of these research findings in COSEE programs and products. This foundation has positioned the COSEE community to play an increasingly central role in the integration of ocean research and education.

Vision:
All ocean educators and scientists have multiple entry points to professional development shown to be effective for diverse cultural and geographic audiences.

Emerging technologies, social networks, and new learning venues make ocean discoveries available to all learners and allow COSEE to reach audiences in new ways.

Ocean scientists and educators proactively infuse Ocean Literacy concepts into standards, teaching materials, and programs across the science disciplines, as well as the formal to informal science education continuum.

The ocean science community fully engages the learning science community in conducting research on topics of relevance to ocean sciences and applies those finding to ocean sciences education.

Priority 4: An expanded and sustainable Network dedicated to excellence in ocean sciences education

An "order of magnitude" increase in the impact of ocean sciences education is possible only through collaboration on a large scale and requires a Network that is unified and well coordinated, well-respected for its effective programs, and trusted to for its high quality work. Two-way communications and increased use of information and communication technologies will drive the Network's growth and evolution. Well-connected internally, the Network is capable of reflection and adaptive change. Well-connected externally, the Network is well placed in the STEM education reform movement, in the science research community and in efforts to expand the talent and diversity of our Nation's STEM work force. A challenge remains to strategically optimize the efficiency and capacity of the Network and its internal and external connections.

A strong foundation for this robust, dynamic Network has been established through the COSEE governance structure and the trust built between Network members. The capacity of individuals and institutions to develop effective programs, to catalyze strong interactions between scientists and educators, and to scale-up effective programs has grown tremendously over the last decade. Cross-Center working groups, experience facilitating ocean sciences broader impact activities, and partnership-building between the Network and other organizations has resulted in Network-wide activities such as the national ocean literacy movement, the annual ocean scientist survey, and the recognition of COSEE at professional society meetings. As the science of the function of networks evolves and the use of communication tools such as social networking, webinars, and videoconferencing grows, the Network can leverage its existing capacity, trust, and governance structure to reach new and more diverse audiences.

Vision:

Knowledge of how complex networks function optimizes the efficiency and capacity of the COSEE Network to increase the prominence of ocean sciences.

The Network strategically partners with professional organizations and institutions to increase the engagement of ocean scientists.

Emerging communication and informational technologies allow for more efficient leveraging and dissemination of the Network's resources, tools, and products.

An online database serving the ocean sciences community allows efficient access and use of comprehensive resources for scientists to engage in broader impact activities.

Building on its past achievements and established infrastructure, the National COSEE Network will meet the visions for its future through new innovative strategies and partnerships. COSEE will incorporate the products and results of broader NSF investments such as those emerging in cyberinfrastructure to provide new capabilities and tools with which the Network can reach scientists, educators, students, and the public. Research on science learning and teaching and new research-based understandings of how to better serve diverse audiences will allow the Network to fully integrate ocean sciences research and education for the benefit of the Nation.